COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

(1) Field of the Invention:

The present invention relates to a communication system, and more particularly to a communication system for performing WDM (Wavelength Division Multiplex) optical communications.

(2) Description of the Related Art:

The optical communication network technology is a core technology for establishing the foundation of information communication networks. In view of growing demands in recent years for a wider range of more sophisticated information services, efforts are being made to promote the quick development of the optical communication network technology.

WDM, which is finding wide use in the field of recent optical communications, refers to a process of multiplexing different wavelengths of light to transmit a plurality of signals simultaneously over a single optical fiber.

WDM systems have a supervisory channel for supervising an optical signal, known as OSC (Optical Supervisory Channel). The supervisory channel is used to supervise WDM system nodes.

Problems of the conventional supervisory channel are that it is not flexible enough and suffers a lack of

convenience because a fixed frequency is assigned to the supervisory channel between sections for WDM communications.

FIG. 10 of the accompanying drawings shows a conventional WDM system that is suffering problems. As shown in FIG. 10, a WDM terminal node 500 comprises optical transmission units 501, 502, a supervisory control unit 511, and a wavelength multiplexer 512.

The optical transmission unit 501 comprises an optical device 501a for emitting a main optical signal having a fixed wavelength λ1, and the optical transmission unit 502 comprises an optical device 502a for emitting a main optical signal having a fixed wavelength λ2. The optical transmission units 501, 502 are units that the user can install and replace as desired.

The supervisory control unit 511 emits an optical supervisory channel signal having a fixed wavelength λ3. Alternatively, the supervisory control unit 511 may be installed in another node, and the WDM terminal node 500 may receive an optical supervisory channel signal having a fixed wavelength λ3 from the supervisory control unit 511 installed in the other node. The wavelength multiplexer 512 multiplexes the optical signals emitted from the optical transmission units 501, 502 and the supervisory control unit 511 into a wavelength-multiplexed signal, and outputs the wavelength-multiplexed signal over a single optical fiber.

It is assumed that the user owns, in its inventory, only an optical transmission unit 503 comprising an optical device 503a for emitting a main optical signal having a fixed wavelength λ3. When the optical transmission unit 502 becomes faulty, however, the user cannot use the optical transmission unit 503 from the inventory to replace the optical transmission unit 502 because the optical signal of the wavelength λ3 has already been used by the supervisory control unit 511 or the optical supervisory channel signal of the fixed wavelength λ3 is being received from the other node. Consequently, the conventional WDM system suffers a lack of convenience due to the assignment of the fixed wavelength to the optical supervisory channel signal.

In recent years, networks are becoming larger in size and more complex in structure. In such larger and more complex networks, the conventional band available for OSC transmission fails to transmit sufficient control information, resulting in a reduction in the system efficiency.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a communication system for performing WDM optical communications efficiently with variably set supervisory control channels.

To achieve the above object, there is provided in

accordance with the present invention a communication system for performing WDM optical communications. The communication system includes a WDM device for providing supervisory control channels for supervising optical communications, the supervisory control channels including a first optical supervisory channel whose transmission band falls outside of the transmission band for main optical signals, and a second supervisory channel whose transmission band falls in an idle band in the transmission band for the main optical signals, the WDM device including supervisory control channel setting means for variably setting the supervisory control channels and WDM transmitting means for wavelength-multiplexing and -demultiplexing the supervisory control channels and the main optical signals, and a network managing device including setting information indicating means for indicating setting information for setting the supervisory control channels to the WDM device, and operating state managing means for managing a network operating state.

The above and other objects, features, and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrative of the

principles of a communication system according to the present invention;

FIG. 2 is a block diagram of an integrated-type WDM device;

FIG. 3 is a block diagram of a transponder-type WDM device;

FIG. 4 is a block diagram showing an internal structure of a WDM device;

FIG. 5 is a block diagram showing an internal structure of a WDM device;

FIG. 6 is a block diagram showing an internal structure of a WDM device according to a modification;

FIG. 7 is a block diagram showing an internal structure of a WDM device according to another modification;

FIG. 8 is a block diagram showing a structure of a repeater;

FIG. 9 is a block diagram of a ring network constructed of optical ADMs; and

FIG. 10 is a block diagram of a conventional WDM system that is suffering problems.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates the principles of a communication system 1 according to the present invention. The communication system 1 comprises a plurality of WDM devices 10-1 through 10-n for performing bidirectional WDM

communications between sections, a network managing device 20 for managing a network that is made up of the WDM devices 10-1 through 10-n and transmission devices connected to the WDM devices 10-1 through 10-n, and a plurality of repeaters 40 (described later on with reference to FIG. 8) connected to optical fiber cables between the WDM devices 10-1 through 10-n.

The WDM devices 10-1 through 10-n comprise respective supervisory control channel setting means 11-1 through 11-n and respective WDM transmission means 12-1 through 12-n. The WDM devices 10-1 through 10-n, the supervisory control channel setting means 11-1 through 11-n, and the WDM transmission means 12-1 through 12-n may also collectively be referred to as a WDM device 10, a supervisory control channel setting means 11, and a WDM transmission means 12, respectively.

The supervisory control channel setting means 11 variably sets, for each section, supervisory control channels, which include a first optical supervisory channel and a second optical supervisory channel, for effecting supervisory control on optical communications.

The first optical supervisory channel is an optical supervisory channel whose transmission band falls outside of the transmission band for main optical signals, and corresponds to the conventional OSC (Optical Supervisory Channel). The second optical supervisory channel is an optical supervisory channel whose

transmission band falls in an idle band in the transmission band for main optical signals.

The WDM transmission means 12 performs a transmission control process for wavelength-multiplexing and -demultiplexing main optical signals that are transmitted as information signals from the transmission device connected to the WDM device or from an adjacent WDM device, and supervisory control channels as control signals.

The network managing device 20 has a setting information indicating means 21 for indicating setting information to set supervisory channels to the WDM device 10. The setting information includes, for example, wavelength information, section information, and time information.

The wavelength information comprises information indicative of a wavelength that is to be assigned to the second optical supervisory channel. The second optical supervisory channel to which a wavelength λa is assigned is referred to as an optical supervisory channel C. The section information comprises information indicative of a section for which the optical supervisory channel C is to be used. The time information comprises information for setting a time zone in which the optical supervisory channel C is to be used.

The network managing device 20 also has an operating state managing means 22 for managing an

operating state of the overall network. The operating state managing means 22 is supplied with information representing the operating state periodically from the WDM device 10 to which the network managing device 20, and stores the supplied information in a database.

Operation of the communication system 1 shown in FIG. 1 will be described below. The first optical supervisory channel will hereinafter be referred to as an OSC, and the second optical supervisory channel as an optical supervisory channel. First, the setting information indicating means 21 transmits setting information representing that the wavelength to be used by the optical supervisory channel in a section S1 between the WDM device 10-1 and the WDM device 10-2 is set to λ5 and the wavelength to be used by the optical supervisory channel in a section S2 between the WDM device 10-2 and the WDM device 10-3 is set to λ6, to the supervisory control channel setting means 11-1. These wavelengths λ5, λ6 belong to the idle band in the transmission band for main optical signals transmitted in the network.

The supervisory control channel setting means 11-1 transmits setting information representing that the wavelength to be used by the optical supervisory channel in the section S1 is set to λ5 and the wavelength to be used by the optical supervisory channel in the section S2 is set to λ6, via the WDM transmission means 12-1 to the WDM device 10-2, using the OSC that has heretofore been

set as the supervisory channel. Similarly, the supervisory control channel setting means 11-2 transmits setting information representing that the wavelength to be used by the optical supervisory channel in the section S2 is set to λ6, via the WDM transmission means 12-2 to the WDM device 10-3, using the OSC.

In operation, the WDM transmission means 12-1 multiplexes main optical signals having respective wavelengths λ1 through λ4, the optical supervisory channel having the wavelength λ5 that is outputted from the supervisory control channel setting means 11-1, and a supervisory control channel as the OSC having a wavelength λosc, into a multiplexed signal, and transmits the multiplexed signal to the WDM device 10-2.

The WDM transmission means 12-2 multiplexes the main optical signals having the respective wavelengths λ1 through λ4, the optical supervisory channel having the wavelength λ6 that is outputted from the supervisory control channel setting means 11-2, and the supervisory control channel as the OSC having the wavelength λosc, into a multiplexed signal, and transmits the multiplexed signal to the WDM device 10-3.

As described above, the communication system 1 employs the idle band in the transmission band for the main optical signals as the transmission band for the optical supervisory channel to chiefly transmit operation control information, and settings of the optical

supervisory channel, e.g., wavelength settings, are variably changed between the sections. The settings that are variably changed are indicated to the WDM devices using the existing OSC.

Since the transmission bandwidth is increased by the supervisory control channels that include the existing OSC and the newly added optical supervisory channels, the communication system 1 can transmit more control information than the conventional communication system, can be used in extended networks with sufficient control information, and has its efficiency increased in extended network environments. The communication system 1 may use only the OSC for initializing the operation control process and may use both the OSC and the optical supervisory channel for the transmission of operational control information.

In addition, the communication system 1 can have its operational flexibility increased because the optical supervisory channels between the sections of the WDM devices 10 can variably be set.

Two specific arrangements of the WDM device 10 will be described below. These two specific device forms include an integrated-type WDM device and a transponder-type WDM device. FIG. 2 shows in block form the integrated-type WDM device. An integrated-type WDM device receives and multiplexes main optical signals to which wavelengths for WDM are assigned.

As shown in FIG. 2, WDM devices 10a-1, 10a-2 are connected to each other by an optical fiber. To the WDM devices 10a-1, 10a-2, there are connected respective sets of transmission devices 3a, 3b, 3c and 3d, 3e, 3f for processing signals of the SONET transmission interface, for example.

The transmission devices 3a, 3b, 3c emit optical signals for WDM to which respective wavelengths $\lambda1$, $\lambda2$, $\lambda3$ are allocated. The WDM device 10a-1 has a supervisory control channel setting means 11 for emitting an optical supervisory channel having a wavelength $\lambda4$ and a supervisory control channel having a wavelength λosc, and a multiplexer (MUX) 12a, which corresponds to the MUX function of the WDM transmission means 12, for multiplexing main optical signals having respective wavelengths $\lambda1$, $\lambda2$, $\lambda3$ and supervisory control channels having respective wavelengths $\lambda4$, λosc into a multiplexed signal and transmitting the multiplexed signal to the WDM device 10a-2 over an optical fiber.

The WDM device 10a-2 has a demultiplexer (DMUX) 12b, which corresponds to the DMUX function of the WDM transmission means 12, for receiving and demultiplexing the transmitted multiplexed signal into the main optical signals having the respective wavelengths $\lambda1$, $\lambda2$, $\lambda3$ and the supervisory control channels having the respective wavelengths $\lambda4$, λosc, and transmitting the main optical signals to the transmission devices 3d, 3e, 3f and the

supervisory control channels to a device controller 13. Based on the supervisory control channels, the device controller 13 performs an internal control process to initialize the WDM device 10a-2 and set circuit links.

FIG. 3 shows in block form the transponder-type WDM device. A transponder-type WDM device has transponders, which correspond to the optical transmission units shown in FIG. 10, for assigning wavelengths for WDM to main optical signals that are supplied from external circuits thereby to multiplex the main optical signals.

As shown in FIG. 3, WDM devices 10b-1, 10b-2 are connected to each other by an optical fiber. To the WDM devices 10b-1, 10b-2, there are connected respective sets of transmission devices 30a, 30b, 30c and 30d, 30e, 30f for processing signals of the SONET transmission interface, for example.

The transmission devices 30a, 30b, 30c generate TDM (Time-Division-Multiplexed) main optical signals, respectively, to which one wavelength $\lambda 0$ is assigned. The WDM device 10b-1 has a supervisory control channel setting means 11 for emitting an optical supervisory channel having a wavelength $\lambda 4$ and a supervisory control channel having a wavelength λosc, and a plurality of transponders 15a, 15b, 15c.

The transponder 15a converts the main optical signal having the wavelength $\lambda 0$ which has been transmitted from the transmission device 30a into a main optical

signal having a wavelength $\lambda1$ for WDM. The transponder 15b converts the main optical signal having the wavelength $\lambda0$ which has been transmitted from the transmission device 30b into a main optical signal having a wavelength $\lambda2$ for WDM. The transponder 15c converts the main optical signal having the wavelength $\lambda0$ which has been transmitted from the transmission device 30c into a main optical signal having a wavelength $\lambda3$ for WDM.

The WDM device 10b-1 also has a multiplexer 12a for multiplexing the main optical signals having the respective wavelengths $\lambda1$, $\lambda2$, $\lambda3$ and the supervisory control channels having the respective wavelengths $\lambda4$, λosc into a multiplexed signal and transmitting the multiplexed signal to the WDM device 10b-2 over an optical fiber.

The WDM device 10b-2 has a demultiplexer 12b for receiving and demultiplexing the transmitted multiplexed signal into the main optical signals having the respective wavelengths $\lambda1$, $\lambda2$, $\lambda3$ and the supervisory control channels having the respective wavelengths $\lambda4$, λosc, and transmitting the main optical signals to the transmission devices 30d, 30e, 30f and the supervisory control channels to a device controller 13. Based on the supervisory control channels, the device controller 13 performs an internal control process to initialize the WDM device 10b-2 and set circuit links.

Internal structures and operation of the WDM

devices 10a-1, 10b-1 will be described in detail below. FIG. 4 shows in block form the internal structure of the WDM device 10a-1. As shown in FIG. 4, the MUX 12a comprises an optical switch 12a-1 and a MUX control means 12a-2, and the supervisory control channel setting means 11 comprises a supervisory information setting means 11a, electro-optical (E/O) converters 11b-1, 11b-2, and wavelength converting means 11c-1, 11c-2.

The network managing device 20 indicates a wavelength λn in the idle band in the transmission band for the main optical signals as a wavelength to be used by an optical supervisory channel, to the WDM device 10a-1. The supervisory information setting means 11a transmits supervisory control information, which includes an operating state of the WDM device 10a-1 to be transmitted via the optical supervisory channel, e.g., cross-connect information relative to Add/Drop for upstream and downstream stations, and fault information, to the electro-optical converter 11b-1 that converts the supplied information into an optical signal. The supervisory information setting means 11a also transmits supervisory control information, which includes setting information to be transmitted via OSC and other information representing the number of wavelengths of WDM, a bit rate, the number of WDM devices, etc., to the electro-optical converter 11b-2 that converts the supplied information into an optical signal.

The wavelength converting means 11c-1 converts the optical signal from the electro-optical converter 11b-1 into an optical signal having a wavelength λn, and transmits the optical signal having the wavelength λn to the optical switch 12a-1. The wavelength converting means 11c-2 converts the optical signal from the electro-optical converter 11b-2 into an optical signal having a wavelength λosc, and transmits the optical signal having the wavelength λosc to the MUX control means 12a-2.

The optical switch 12a-1 performs a switching action for transmitting the main optical signals having the respective wavelengths λ1, λ2, λ3 supplied from the transmission devices 3a, 3b, 3c and the optical supervisory channel having the wavelength λn supplied from the supervisory control channel setting means 11, to input ports of the MUX control means 12a-2. Switching settings of the optical switch 12a-1 are given from the supervisory information setting means 11a.

The input ports of the MUX control means 12a-2 are assigned to the respective wavelengths because the input ports comprise respective waveguides dedicated to particular wavelengths. The optical switch 12a-1 selectively applies the main optical signals and the optical supervisory channel which have been received to the respective input ports of the MUX control means 12a-2.

The MUX control means 12a-2 multiplexes the main optical signals having the respective wavelengths λ1, λ2,

$\lambda 3$ and the optical supervisory channels having the respective wavelengths λn, λosc into a WDM signal, and transmits the WDM signal over an optical fiber.

FIG. 5 shows in block form the internal structure of the WDM device 10a-2. As shown in FIG. 5, the DMUX 12b comprises an optical switch 12b-1 and a DMUX control means 12b-2, and the device controller 13 comprises opto-electric (O/E) converters 13a-1, 13a-2 and an internal control means 13b.

The DMUX control means 12b-2 demultiplexes the WDM signal transmitted from the WDM device 10a-1 into the main optical signals and the optical supervisory channels, and outputs the main optical signals to the optical switch 12b-1 and the optical supervisory channel having the wavelength λosc to the device controller 13. The optical switch 12b-1 performs a switching action for transmitting the main optical signals having the respective wavelengths $\lambda 1$, $\lambda 2$, $\lambda 3$ to the transmission devices 3d, 3e, 3f and the optical supervisory channel having the wavelength λn to the device controller 13.

The opto-electric converters 13a-1, 13a-2 convert the optical supervisory channel OSC having the wavelength λosc and the optical supervisory channel having the wavelength λn into respective electric signals, and supply the electric signals to the internal control means 13b. Based on the supplied electric signals, the internal control means 13b performs an internal control process on

the WDM device 10a-2. Switching settings of the optical switch 12b-1 and setting information of the optical supervisory channels are indicated in advance to the WDM device 10a-2 using the OSC.

Modifications of the MUX 12a and the DMUX 12b will be described below. In each of the MUX 12a and the DMUX 12b described above, the optical signal system effects a switching control process for WDM control. According to the modifications, however, an electric signal system effects a switching control process for WDM control.

FIGS. 6 and 7 show internal structures of the WDM devices according to the respective modifications.

In FIG. 6, a WDM device 120-1 has a MUX 120a including electric signal receivers 121a, 122a, 123a, switches 121b, 122b, 123b, 124b, electro-optical converters 121c, 122c, 123c, 124c, and a MUX control means 125.

The network managing device 20 indicates a wavelength λn in the idle band in the transmission band for the main optical signals as a wavelength to be used by an optical supervisory channel, to the WDM device 120-1. The WDM device 120-1 also has a supervisory control channel setting means 110 which transmits supervisory control information to be transmitted via an optical supervisory channel to the switches 121b, 122b, 123b, 124b in the MUX 120a and also transmits control information to

be transmitted via OSC to the MUX control means 125.

The electric signal receivers 121a, 122a, 123a receive respective electric signals transmitted as information signals from transmission devices 3-1, 3-2, 3-3. The switches 121b, 122b, 123b, 124b receive output signals from the electric signal receivers 121a, 122a, 123a and an electric signal representing the optical supervisory channel transmitted from the supervisory control channel setting means 110, and perform a switching action to selectively send the supplied signals to the electro-optical converters 121c, 122c, 123c, 124c. Switching settings of the switches 121b, 122b, 123b, 124b are given from the supervisory control channel setting means 110.

The electro-optical converters 121c, 122c, 123c, 124c convert the supplied electric signals into corresponding optical signals which have preassigned wavelengths, and transmit the optical signals to the MUX control means 125. The MUX control means 125 multiplexes the main optical signals having the respective wavelengths $\lambda1$, $\lambda2$, $\lambda3$ and the optical supervisory channels having the respective wavelengths λn, λosc into a WDM signal, and transmits the WDM signal over an optical fiber.

In FIG. 7, a WDM device 120-2 has a DMUX 120b including a DMUX control means 126, opto-electric converters 121d, 122d, 123d, 124d, switches 121e, 122e, 123e, 124e, and electric signal transmitters 121f, 122f,

123f.

The DMUX control means 126 receives and demultiplexes a supplied WDM signal, outputs main optical signal and an optical supervisory channel to opto-electric converters 121d, 122d, 123d, 124d, and also output an OSC to a device controller 130. The opto-electric converters 121d, 122d, 123d, 124d convert the supplied signals into optical signals, and output the optical signals to the switches 121e, 122e, 123e, 124e. The switches 121e, 122e, 123e, 124e effects a switching action to supply the main optical signals to the electric signal transmitters 121f, 122f, 123f and the optical supervisory channel to the device controller 130.

The electric signal transmitters 121f, 122f, 123f transmit the main optical signals to respective transmission devices 3-4, 3-5, 3-6. Based on the OSC and the optical supervisory channel that have been supplied, the device controller 130 performs an internal control process. Switching settings of the switches 121e, 122e, 123e, 124e and setting information of the optical supervisory channels are indicated in advance to the WDM device 120-2 using the OSC.

The repeaters 40 shown in FIG. 1 will be described below. FIG. 8 shows in block form a structure of each of the repeaters 40. The repeater 40 controls an internal repeater amplifier based on the information of a received OSC, inserts its own state information into an

OSC to be transmitted, multiplexes the OSC and main optical signals, and transmits a multiplexed signal.

The repeater 40 comprises a repeater control means 41, an opto-electric (O/E) converter 42a, an electro-optical (E/O) converter 42b, and an amplification controller 43. The amplification controller 43 comprises an optical demultiplexing means 43a, an optical amplifier 43b, and an optical multiplexing means 43c.

The optical demultiplexing means 43a demultiplexes a WDM signal, which comprises main optical signals, an OSC, and an optical supervisory channel that have been multiplexed, transmits the main optical signals and the optical supervisory channel to the optical amplifier 43b, and transmits the OSC to opto-electric converter 42a.

The opto-electric converter 42a converts the OSC into an electric signal. The repeater control means 41 controls an amplification process of the optical amplifier 43b in the amplification controller 43 based on the information of the OSC that has been converted into the electric signal. The repeater control means 41 also adds an operating state of the repeater 40 to the information of the OSC, and transmits it to the electro-optical converter 42b.

The electro-optical converter 42b converts the newly generated OSC into an optical signal, and transmits the optical signal to the optical multiplexing means 43c.

The optical multiplexing means 43c multiplexes the main optical signals and the optical supervisory channel that have been amplified by the optical amplifier 43b and the OSC transmitted from the electro-optical converter 42b into a WDM signal, and transmits the WDM signal.

A ring network including optical ADMs (Add Drop Multiplexers) which incorporates the principles of the present invention will be described below. FIG. 9 shows in block form such a ring network including optical ADMs.

As shown in FIG. 9, optical ADMs 101, 102, 103, 104 are interconnected by optical fibers, making up a ring network, and a network managing device 20 is connected to the optical ADM 104. Transmission devices 101a, 102a, 103a, 104a are connected respectively to the optical ADMs 101, 102, 103, 104.

The optical ADMs 101, 102, 103, 104 receive and multiplex signals transmitted from the transmission devices 101a, 102a, 103a, 104a (Add). The optical ADMs 101, 102, 103, 104 also demultiplex a multiplexed signal and transmit desired signals to the transmission devices 101a, 102a, 103a, 104a (Drop).

The WDM device 10 according to the present invention is incorporated in each of the optical ADMs 101, 102, 103, 104 of the ring network. A multiplexed signal composed of main optical signals and supervisory control channels is transmitted between the optical ADMs 101, 102, 103, 104. Optical supervisory channels to which desired

wavelengths have been assigned are also transmitted between the optical ADMs 101, 102, 103, 104. The network managing device 20 sets supervisory channels for the optical ADMs 101, 102, 103, 104 and manages an operating state of the network.

As described above, in the communication system 1 according to the present invention, the WDM device 10 variably sets supervisory control channels for WDM transmission, and the network managing device 20 indicates setting information of the supervisory control channels and manages an operating state of the network.

With such an arrangement, since the communication system is capable of adaptively setting supervisory control channels, the communication system is highly flexible and performs WDM communications efficiently.

In the above description, the wavelength of the OSC which is the first optical supervisory channel is set to the fixed wavelength λosc. However, the wavelength of the OSC may easily be made variable when it is controlled in the same manner as with the second optical supervisory channel.

In the communication system according to the present invention, as described above, the WDM device variably sets supervisory control channels that include a first optical supervisory channel whose transmission band falls outside of the transmission band for main optical signals and a second supervisory channel whose

transmission band falls in an idle band in the transmission band for main optical signals, and the network managing device indicates setting information of the supervisory control channels and manages an operating state of the network. Inasmuch as the communication system is capable of adaptively setting supervisory control channels, the communication system is highly flexible and performs WDM communications efficiently.

The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.